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Development of a Piezo Scanning System for the Micro-Column Scanning Electron Microscope (MSEMS)

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Abstract

The scanning electron microscope (SEM) is widely employed, from life sciences to semiconductor metrology, for determining both nanoscale topographical features as well as elemental composition for many different types of specimens. State-of-the-art laboratory SEMs are powerful instruments for advanced investigation of biological samples, mineralogy, etc. Laboratory SEMs are too large to be *in situ* space instruments, however. We are developing a miniature prototype SEM with similar capabilities as a laboratory SEM for potential NASA space flight missions. The instrument's optical column is predicted to be just 25 mm. Unique to our SEM development is the carbon nanotube cold field emission cathode, a MEMS micro-column, and a piezoelectric stage, used for scanning the sample. Traditional SEMs use scanning coils in the column to raster the electron beam over a sample. To enable the miniaturization of the optical column and for the purpose of eliminating unwanted image aberrations, the micro-column SEM will not contain these scanning coils. In contrast, our SEM system employs a fixed, highly-focused electron beam, and a piezoelectric stage to scan the sample, with the entire micro-column electron source moving relative to a sample. This scanning mechanism enables the instrument to be simpler and the entire SEM system to have a size of a shoebox. In this poster, we report the development of a piezoelectric scanning stage system using the robust LabVIEW software interface. In order to produce an SEM image the piezoelectric stage must be synchronized with the secondary electron detector signal. In addition, we will report on a multiple scanning mode for producing images with a higher signal-to-noise ratio.

Micro-Column SEM

An SEM image is created by the beam hitting the sample and exciting electrons in a given volume of interaction, causing the emission of both secondary and backscatter electrons. Secondary electrons carry information about topography, while backscatter electrons are much higher in energy and carry information about elemental composition. The electron beam is emitted by cold field emission of a carbon nanotube tip (see figure 1). The detector is an Everhart-Thornley type detector, for imaging secondary electrons created by the e-beam, as well as the secondary electrons from back-scatter electron interactions. Several vacuum pumps are used in laboratory SEMs to achieve low pressures needed for field emission.

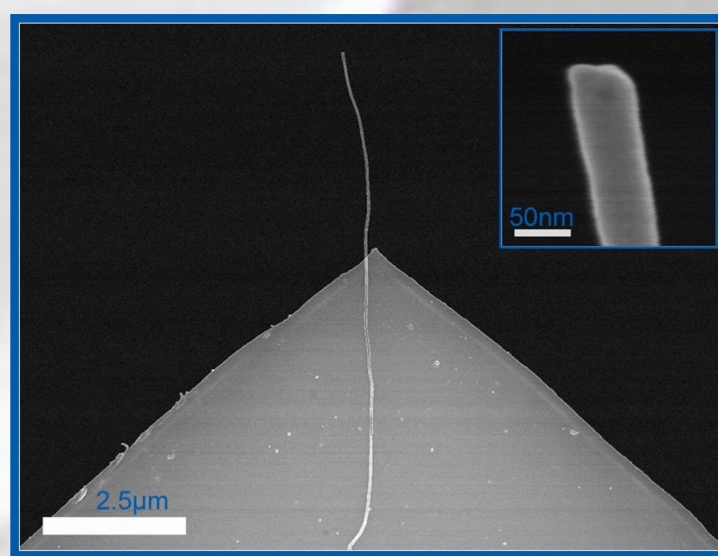

Figure 1: Carbon nanotube tip

Piezo Scanning Stage

We are using a Mad City Labs Nano-Drive controller with the X and Y axes decoupled from the Z axis. For this test, only the X and Y axes are used. The motion of the stage is controlled by piezoelectric materials; when a voltage difference is introduced across the material, a force is produced, moving the stage. There are separate piezos for each X and Y – this reduces hysteresis.


Figure 2: Scanning Stage with samples

Scan Pattern

The scan pattern used is a raster pattern as shown in figure 3. Two images are produced during each scan. One image is obtained as the sample moves leftwards, the other is obtained when the sample moves to the right. Because the scan motion isn't perfectly linear throughout, these two images are not identical. Though a scan patterned after a triangle wave would be faster, it would contain distortions caused by the stage movement.

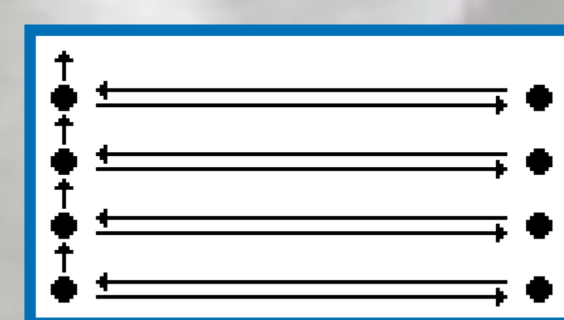
Figure3: Scan Pattern

Calibration and Testing

To test the scanning system, we fixed the beam on a Hitachi S-4000 laboratory SEM by unplugging and grounding the wires carrying signals going to the microscope from the Gatan DigiScan controller box. We made a mount for our own piezo stage so that it would fit on top of the sample holder. We then inserted it into the sample chamber. We tapped into the signal from the Everhart-Thornley electron detector and sampled it using an *Data Translation* A/D converter (see figure 4). We sent commands to the stage through an electrical feed-through in a ConFlat flange (see figure 5). Figure 6 shows the inside of the sample chamber, and the clearance between the objective lens and the samples on top of the scanning stage. This method allowed us to directly test if our scanning system could produce an image similar to an image produced by a laboratory SEM.

The data acquisition times must be calibrated so that data is not taken when the stage is accelerating or decelerating, as this will cause distortion of the picture. The step response of the system can be seen in figure 7. Only points sampled along the linear region are significant.

Figure 4: Acquiring the detector signal

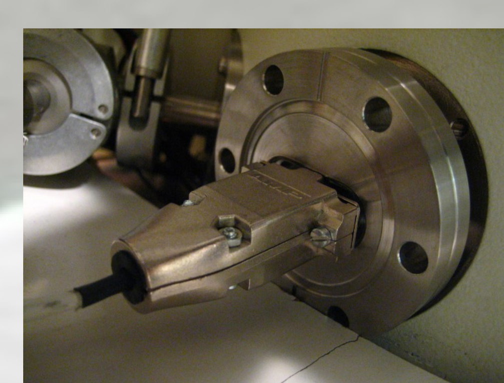
Figure 5: Electrical feed-through


Figure 6: Inside the sample chamber

Analysis and Conclusions


Figure 8: Current size of SEM

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[1] Landis, Geoffrey A. "Degradation of the Lunar Vacuum by a Moon Base." *Acta Astronautica*. Vol. 21, No. 3, 183-187. 1990.
[2] Goldstein et al. Scanning Electron Microscopy and X-Ray Analysis, 3rd ed. New York: Springer, 2003